Method of Test for

WEIGHT PER CUBIC FOOT, YIELD, AND AIR CONTENT (GRAVIMETRIC) OF CONCRETE

DOTD Designation: TR 201-84

METHOD A – CONCRETE WITH A NORMAL SLUMP OF ONE INCH OR GREATER

Scope

1. This method of test covers the procedure for determining the weight per cubic foot or cubic meter of freshly mixed concrete with a slump of 1 in. or greater, and gives formulas for calculating the yield, that is, volume of concrete produced from a mixture of known quantities of the component materials; the actual cement factor; and the air content of the concrete.

NOTE: The air content calculated by this test method is for general information only, and is not to be used for job control.

Apparatus

2. (a) *Balance* - A balance or scale accurate to within 0.3% of the test load at any point within the range of use.

(b) *Tamping Rod* - A round, straight steel rod, 5/8 in. in diameter and approximately 24 in. in length, having the tamping end rounded to a hemispherical tip the diameter of which is 5/8 in.

(c) *Measure* - A cylindrical container made from metal that is not readily attacked by cement paste. It shall be watertight and sufficiently rigid to retain its form and calibrated volume under rough usage. Measures must be machined to accurate dimensions on the inside and be provided with handles. The top rim shall be smooth and plane so that a 0.02 in. feeler gage cannot be inserted between the rim and a piece of 1/4 in. or thicker plate glass laid over the top. The top shall be parallel to the bottom within 0.5 degree. Measures with a metal thickness less than 0.20 in. shall be reinforced around the upper 1.5 in. with a steel band to provide a minimum thickness of 0.20 in. Depending upon the nominal maximum size of coarse aggregate in the concrete, the capacity and dimensions of the measure shall conform to the limits in Table 1 or 2.

NOTE: Dimensional tolerances and thicknesses of metal prescribed here are intended to be applied to measures acquired after January 1, 1978.

TABLE 1
Dimensions of Measures

Capacity, ft.^{3}	Inside Diameter, in.	Inside Height, in.	Minimum Thicknesses of Metal, in.		Nominal Max. Size of Aggregate, in.*
			Bottom	Wall	
1/2	10.0 ± 0.1	11.0 ± 0.1	0.20	0.12	2 or less
1	14.0 ± 0.1	11.2 ± 0.1	0.20	0.12	Over 2

* Based on sieves with square openings. Nominal maximum size is the largest sieve size listed in the applicable specification, upon which any material is permitted to be retained.

(d) *Strike-off Plate* - A flat, rectangular metal plate at least 1/4 in. thick or a glass or acrylic plate at least 1/2 in. thick with a length and width at least 2 in. greater than the diameter of the measure with which it is to be used.

3. Determine the calibrated volume of the measure in accordance with DOTD Designation: TR 640.

Sample

4. Obtain the sample of freshly mixed concrete in accordance with DOTD Designation: S 301 of the Materials Sampling Manual.

Procedure

5. (a) *Consolidation* - Place the concrete in the measure in three layers of approximately equal volume. Rod each layer with 25 strokes of the tamping rod when the 0.5 $ft.^3$ measure is used and 50 strokes when the 1 $ft.^3$ measure is used. Rod the bottom layer throughout its depth, but do not allow the rod to forcibly strike the bottom of the measure. Distribute the strokes uniformly over the cross section of the measure; for the top two layers, penetrate about 1 in. into the underlying layer. After each layer is rodded, tap the sides of the measure smartly 10 to 15 times to close any voids left by the tamping rod and to release any large bubbles of air that may have been trapped. When adding the final layer, care should be taken not to overfill the measure.

On completion of consolidation, the measure must not contain a substantial excess or deficiency of concrete. An excess of concrete protruding approximately 1/8 in. above the top of the mold is optimum. If the measure contains more than 1/8 in. of concrete above the top of the mold at completion of consolidation, remove a representative portion of the excess concrete with a trowel or scoop immediately following completion of consolidation and before the measure is struck off. If the measure does not contain enough concrete at completion of consolidation, a small quantity of concrete may be added before the measure is struck off.

(b) *Strike-off, Cleaning and Weighing* - After consolidating the concrete, strike off and finish the top surface with the flat strike-off plate taking care to leave the measure just level full. All excess concrete shall then be cleaned from the exterior and the filled measure weighed to an accuracy consistent with the requirements of 2(a).

Calculations

6. (a) *Weight Per Cubic Foot* - Calculate the net of the measure from the gross weight. Calculate the weight per cubic foot by dividing the net weight by the calibrated volume of the measure used, determined as described in Section 3.

Example: - Assume that a measure weighing 18.4 lbs. and having a calibrated volume of .5005 $ft.^3$ was used to obtain a gross weight of 88.6 lbs. (weight of measure filled with concrete). The net weight of the concrete is therefore equal to 88.6 ÷ 18.4 = 70.2 lbs. The weight per cubic foot is then equal to 70.2 ÷ .5005 $ft.^3$ = 140.3 $lbs/ft.^3$.

(b) *Yield* - Calculate the yield (volume of concrete produced per batch) as follows:

$$Y = \frac{W_c + W_{fa} + W_{ca} + W_w}{W}$$

where:

- Y = yield, $ft.^3$
- W_c = total weight of cement in the batch, lb.
- W_{fa} = total weight of fine aggregate in batch in condition used, lb.
- W_{ca} = total weight coarse aggregate in batch in condition used, lb.
- W_w = total weight of mixing water added to batch, lb.
- W = weight of concrete $lb/ft.^3$

NOTE: To convert yield to cubic yards, divide Y by 27

Example: - Assume that the weight per cubic foot calculated in paragraph 6(a) was obtained on a concrete sample taken from a 7 cubic yard batch containing the following weights of component materials:

Cement = 4,277 lb = W_c
Fine Aggregate = 7,826 lb = W_{fa}
Coarse Aggregate = 12,425 lb = W_{ca}
Water = 1,970 lb = W_w

Calculate the yield as follows:

$$Y = \frac{4,277 + 7,826 + 12,425 + 1,970}{140.3}$$

= 188.9 cubic feet or 188.9/27 = 7 cubic

(c) Cement Factor - Calculate the "actual" cement factor as follows:

$$N = \frac{KW_c}{Y}$$

where:

N = number of bags of cement per yd^3 of concrete produced (actual cement factor)
K = A constant factor equal to 0.2872
W_c = total weight of cement in the batch, lb
Y = yield, ft^3

Example: Using the example shown in paragraph 6(b), the cement factor can be calculated as:

$$N = \frac{0.2872 \times 4{,}277}{188.9}$$
$$= 6.5 \text{ bags/yd}^3$$

(d) *Air Content* - Calculate the air content as follows:

$$A = \frac{Y - V}{Y} \times 100$$

where:

A = air content (percentage of voids) in the concrete
Y = yield, ft^3
V = total absolute volume of the component ingredients in the batch, ft^3

Example: The absolute volume of component ingredients can be calculated by dividing the weight of the components by the product of its specific gravity and 62.4. Therefore, the absolute volumes of the component materials shown in the example in paragraph 6(b) are as follows:

$$\text{Cement} = \frac{4277}{3.15 \times 62.4} = 21.8 \text{ ft}^3$$

$$\text{Fine Aggregate} = \frac{7{,}826}{2.62 \times 62.4} = 47.9 \text{ ft}^3$$

$$\text{Coarse Aggregate} = \frac{12{,}425}{2.53 \times 62.4} = 78.7 \text{ ft}^3$$

$$\text{Water} = \frac{1970}{1 \times 62.4} = 31.6 \text{ ft}^3$$

NOTE: The specific gravities for the fine and coarse aggregates are assumed to be 2.62 and 2.53, respectively, for this example only. The specific gravity of cement is 3.15 and is a standard value used in calculating absolute volumes. The specific gravity of water is also standard and a value of 1 is used.

Using these absolute volumes, the total absolute volume of the component ingredients can be calculated as:

$$V = 21.8 + 47.9 + 78.7 + 31.6$$
$$= 180.0 \text{ cubic feet}$$

The air content can then be calculated as follows:

$$A = \frac{188.9 - 180.0}{188.9} \times 100 = 4.7\%$$

Report

7. The values calculated from this test procedure are used for general information only and need not be reported except under special circumstances.

Normal testing time is 15 minutes.

DOTD Designation: TR 201-84
METHOD B - CONCRETE WITH A SLUMP OF LESS THAN 1 INCH

Scope

1. This method of test covers the procedure for determining the weight per cubic foot of freshly mixed concrete with a slump of less than 1 in. Formulas for calculating the yield, actual cement factor, and the air content of the concrete are given in Method A.

Apparatus

2. (a) *Balance* - A balance or scale accurate to within 0.3% of the test load at any point within the range of use.

(b) *Vibrator* - A vibrator having a rigid or flexible shaft capable of providing 7000 vibrations per minute or greater while in use. The outside diameter or side dimension of the vibrating head shall be at least 0.75 in. and not greater than 1.50 in. The length of the vibrating head shall be at least 12 in. and the shaft length shall be at least 24 in.

(c) *Measure* - A cylindrical container conforming to 2(c) in Method A with a metal pipe, having an inside diameter no greater than 0.375 in. larger than the outside diameter or side dimensions of the vibrating head, welded on the outside of the container. The metal pipe shall be at least 12 in. long and shall have a perforated metal bottom.

(d) *Strike-Off Plate* - A flat, rectangular plate conforming to 2(d) in Method A.

Calibration of Measure

3. Determine the calibrated volume of the sample measure in accordance with DOTD Designation: TR 640.

4. Obtain the sample of freshly mixed concrete in accordance with DOTD Designation: S 301 of the Materials Sampling Manual.

Procedure

5. (a) *Consolidation* - Place the concrete in the measure in two layers of approximately equal volume, taking care that no concrete enters the metal pipe. Immediately following the placement of each layer, insert the vibrator head into the metal pipe attached to the measure and vibrate the layer until the surface of the concrete becomes relatively smooth (20-30 seconds). The duration of vibration required will depend on the workability of the concrete and the effectiveness of the vibrator. Care shall be taken not to overvibrate the concrete because overvibration may cause segregation and loss of significant quantities of intentionally entrained air.

On completion of consolidation, the measure must not contain a substantial excess or deficiency of concrete. An excess of concrete protruding approximately 1/8 in. above the top of the mold is optimum. If the measure contains more than 1/8 in. of concrete above the top of the mold at completion of consolidation, remove a representative portion of the excess concrete with a trowel or scoop immediately following completion of vibrating and before the measure is struck off.

(b) *Strike-Off, Cleaning, and Weighing* - After consolidating the concrete, strike off and finish the top surface with the flat strike-off plate, leaving the measure just level full and taking care to prevent concrete from entering the metal pipe attachment. All excess concrete shall then be cleaned from the exterior and the filled measure weighed to an accuracy consistent with the requirements of 2(a).

Calculations

6. (a) *Weight Per Cubic Foot* - Calculate the weight per cubic foot as shown in 6(a) of Method A.

(b) *Yield* - Calculate the yield (volume of concrete produced per batch) as shown in 6(b) of Method A.

(c) *Cement Factor* - Calculate the actual cement factor as shown in 6(c) of Method A.

(d) *Air Content* - Calculate the air content as shown in 6(d) of Method A.

Report

7. Report unit weight as calculated in 6(a) to the nearest 0.1 lb/ft^3.

Normal testing time is 15 minutes.